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Technical Lesson 16

THE STORAGE OR SECONDARY BATTERY

The term "storage battery" has become, since the rise in popularity of radio broadcast receivers, almost as common as the word "Radio". To the average broadcast listener the storage battery is simply a heavy, box-like affair that lights the tubes in his radio set. For the student of radio, however, the storage cell must mean more than that and its construction, action and maintenance should be understood.

There are two predominating types of storage cells in use today. They are the lead plate, sulphuric acid cell, manufactured by the Electric Storage Battery Company and the Edison nickel-iron alkali cell, made by the Edison Storage Battery Company.

DIFFERENCE BETWEEN PRIMARY AND SECONDARY CELLS

There is a marked difference between the primary cell, which has been previously discussed and the secondary cell, which is the object of this lesson.

The primary cell, when exhausted, can only be recharged by replacing the zinc element. If we could send a current through the primary cell opposite to that of the discharging current of the cell, which would restore the elements, we would have a storage cell, but since this is not possible the elements must be replaced.

The secondary cell allows a reverse current, called the charging current, to be sent through it which restores the cell to use again without having to replace any of the elements. The primary cell is useless when discharged, and is thrown away, while the secondary cell may be used over and over again simply by passing an electric current through the cell in the opposite direction of discharge.

The storage battery is made up of two or more cells and each cell consists essentially of one positive and one negative plate immersed in an acid solution.

CONSTRUCTION OF THE LEAD ACID CELL

The Exide type of plate is made of an alloy of soft lead and antimony. This is made into a grid or frame, as shown in Figure 1, of vertical ribs joined together by short horizontal bars. The bars are flush with the surface of the plate on one side and extend only half way through the plate; the opposite side is quite the same but the openings are staggered as shown in Figure 2. This construction of the plate makes a strong rigid frame to hold the active material.

THE ACTIVE MATERIAL

The active material is a paste of litharge, or oxide of lead, mixed with dilute sulphuric acid. This paste is forced into the opening of the plates under great pressure; the pressure together with the adhesive properties of the material combine to hold the paste in place.

When the plates have been completed, i.e., the openings filled with paste, they are then placed in a solution of sulphuric acid and water, called the electrolyte, and given the forming charge. This forming charge consists of passing a current of electricity through the plates and electrolyte which changes one plate to lead peroxide and the other to sponge lead.

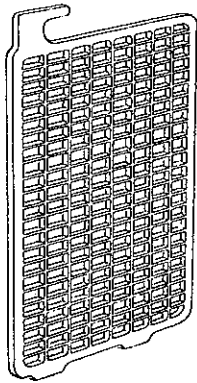


Figure 1

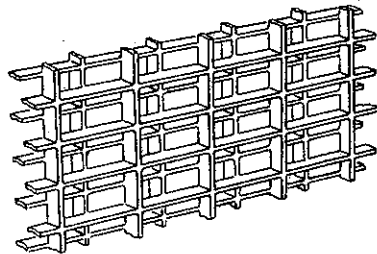


Figure 2

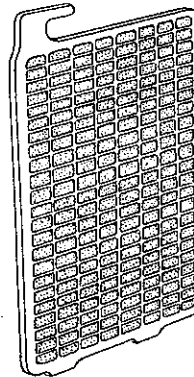


Figure 3

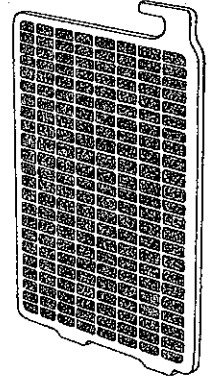


Figure 4

After the forming charge the plates are then taken out of the forming tank. Figure 3 shows the negative plate after this charge. It has been chemically changed to sponge lead and is gray in color. Figure 4 shows the positive plate which has been changed to lead peroxide and which is brown in color.

THE AMPERE HOUR RATING OF THE STORAGE BATTERY

The capacity of a storage cell is rated in ampere hours. The ampere hour is the unit employed to express the equivalent quantity of current represented by current of one ampere flowing through a given circuit for an hour of time. The normal discharge rate for most batteries is generally based on the 8-hour rate of discharge. For example, suppose you have a battery which is rated as having a capacity of 110 ampere-hours, the normal rate of discharge is found by dividing 110 by 8, or 13.75, which means that thirteen and three-quarters amperes can be drawn from the battery for a period of 8 hours. From a theoretical standpoint it would seem that the above battery would deliver 110 amperes for a period of one hour. This, however, from practical experience, has proven to be untrue. As the rate of discharge is increased the ampere-hour capacity will decrease because of the inability of the acid to properly and quickly combine with the active material of the plates at the more rapid rate of discharge.

THE CHEMICAL ACTION OF A LEAD STORAGE BATTERY

When a lead storage cell is put on discharge the current is produced by the acid of the solution going into and combining with the porous part of the plate called the "active material". In the positive plate the active material is lead peroxide and in the negative plate it is metallic lead in a spongy form.

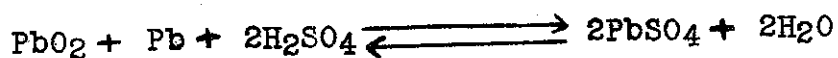
When the sulphuric acid, H_2SO_4 , in the electrolyte combines with the lead, Pb, in the active material of both plates, a compound "lead sulphate", $PbSO_4$, is formed.

As the discharge progresses the electrolyte becomes weaker by the amount of acid that is used in the plates, and the formation of more water due to the chemical combination of the hydrogen, H, and oxygen, O, producing the electric current and incidentally producing the compound of acid and lead called "lead sulphate". This sulphate continues to increase in quantity and bulk, thereby filling the pores of the plates. As the pores of the plates become thus filled with the sulphate, the free circulation of acid into the plates is retarded and, since the acid cannot then get into the plates fast enough to maintain the normal action, the battery becomes less active as indicated by the rapid drop in voltage.

During the charging period direct current must pass through the cells in the direction opposite to that of discharge. This current will reverse the action which took place in the cells during discharge. It will be remembered that, during discharge, the acid of the solution went in and combined with the active material, filling the pores with sulphate and causing the solution to become weaker; reversing the current restores the active material to its original condition and returns the acid to the solution. Thus, during charge, the solution gradually becomes stronger as the sulphate in the plate decreases, until no more sulphate remains and all the acid has been returned to the solution, when it will be of the same strength as before the discharge and the same acid will be ready to be used over again during the next discharge. Since there is no loss of acid by this process, none should ever be added to the solution except to replace that which may be spilled out.

The whole object of charging, therefore, is to drive from the plates the acid which has been absorbed by them during discharge.

The chemical action which occurs in a lead cell during charge and discharge can be represented by the following expression which applies to both plates:



From left to right, this expression represents the chemical reactions during discharge and, from right to left, the chemical reactions during charge.

THE NUMBER OF PLATES IN POSITIVE AND NEGATIVE GROUPS

When the battery is discharging the chemical action taking place is greatest on the positive plate. There is, as a result of this greater chemical action, more heat produced in the plates of the positive group. This heat must be equalized, that is, evenly distributed on both sides of the plates to prevent what is termed "buckling". Buckling is analogous to the warping of a board to which heat has been applied naturally or intentionally at a greater intensity on one side than the other. When a lead-acid-cell plate buckles it has a tendency to loosen the active material. This of course decreases the efficiency of the battery because, without this active material, the battery will not function. To accomplish the even distribution of heat arising in the positive plates, the negative group always consists of one more plate than the positive group and when the groups are assembled the positive plates are surrounded by the negative plates thus assuring a more even temperature on both sides of the positive plates. The negative group is shown in Figure 5 and the positive in Figure 6. Figure 7 shows how the two groups are interleaved so that the negative groups surround the positive.

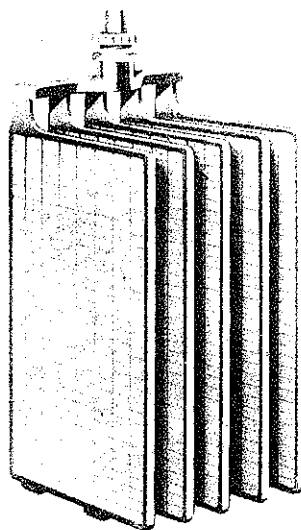


Figure 5

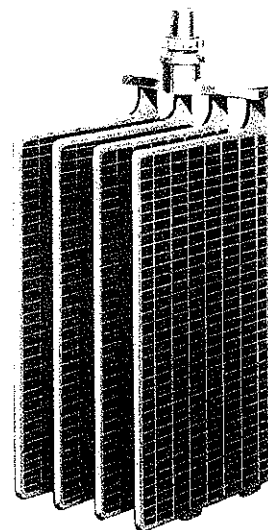


Figure 6

SEPARATORS

When the positive and negative groups are interleaved, specially prepared wooden and rubber separators are placed between the plates to prevent the plates of the negative group from coming in contact with the positive group. The perforated rubber separator, as shown in Figure 8, is placed on each side of each positive plate, and a grooved wooden separator, shown in Figure 9, is placed between each rubber separator and the adjacent negative plate in such a way that the flat side of the wooden separator is against the negative. The active material that is worked loose by the chemical action drops down to the bottom of the jar through the grooves of the wooden separator.

With the plates interleaved and the separators in place the two completely assembled groups are now called the "elements". They are placed in a rubber jar which has a rubber cell cover tightly sealed by means of a special sealing compound. The cover is shown in Figure 10 with the filling and sealing plug fitted in place.

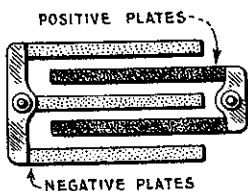


Figure 7

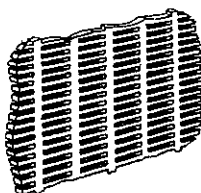


Figure 8

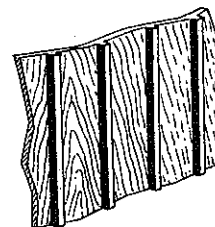


Figure 9

THE COMPLETED CELL

Figure 11 is a cutaway view showing the completed cell. Notice the ribs at the bottom of the jar on which the plates rest; this provides space for the active material, which works from the plates to drop, thus preventing short circuiting of the plates. The channel running around the edge of the top cover is for the sealing compound which is poured in until it is flush with the top of the jar and cover. These cells are now ready to be placed in the battery box which is of wood or composition structure, depending upon the service in which the battery is to be employed.

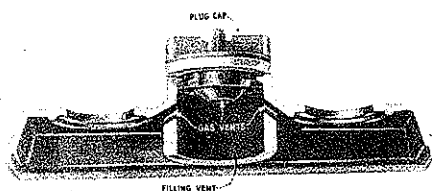


Figure 10

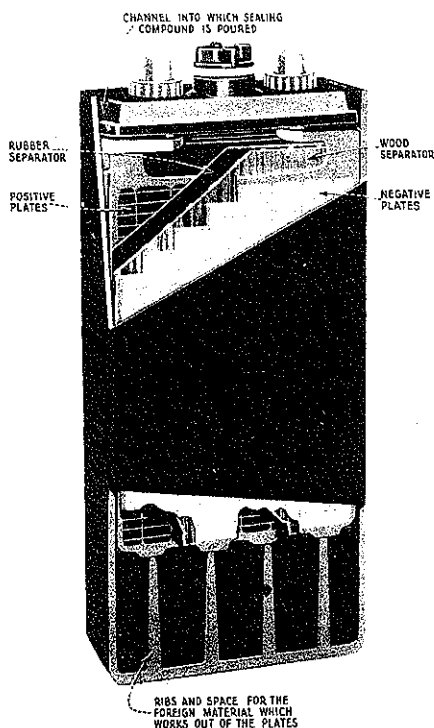


Figure 11

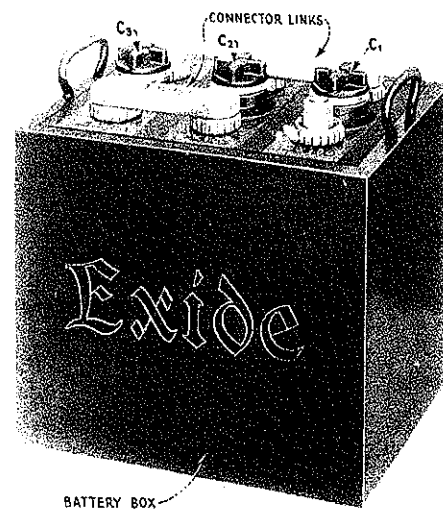


Figure 12

The cells are arranged as shown in Figure 12. In the battery box there has been placed three cells C1, C2 and C3. The connector links are placed on the terminals of the cells after the rubber cover has been sealed in place, and connect the negative terminal of one cell to the positive terminal of the next cell and so on. All cells must be connected in series and, when completed, the battery has two terminal posts, - one negative and one positive.

THE ELECTROLYTE USED IN THE BATTERY, SPECIFIC GRAVITY

The completed battery shown in Figure 12 is now ready for the electrolyte. This is the chemical solution which acts on the plates. Sulphuric acid is the base of the electrolyte and is mixed with pure distilled water, that is, water which contains no foreign substance. The percentage of acid varies from 22 to 37 percent by volume, depending upon the type of cell. When a solution having a specific gravity of 1.200 is required, and 1 part of acid to 4.3 parts of distilled water. For a specific gravity of 1.275, add 1 part of acid to 2.8 parts of water and, when a solution having a specific gravity of 1.300 is desired, add 1 part of acid to 2.5 parts of water.

This solution is generally placed in the battery by the manufacturer and it is not probable that the consumer will have this duty to perform. Yet should the buyer have this to do the electrolyte will come mixed and placing it in the battery is simply a matter of removing the sealing and vent plug from the top of each cell and carefully pouring the solution in the cell. The electrolyte should cover the plates three-quarters of an inch. Do not use a metal funnel or allow the acid to come in contact with a metal container. A glass or earthenware container only should be employed for this purpose.

THE HYDROMETER

As explained, the electrolyte has weight, and to measure this weight an instrument known as the "hydrometer" is employed. In the process of charging and discharging the battery the acid, during discharge, combines with the active material of the plates and when being charged the acid is returned to the electrolyte. As the plates absorb the acid during discharge the density of the solution becomes lighter and it will not, therefore, support the weight of the hydrometer as it will when the acid is combined with the water.

The hydrometer is constructed on principles which are based on the density of the fluid it is to measure. This instrument, used to show the state of charge of the storage battery, is constructed as follows: The hydrometer is a long hollow glass tube, the general appearance of which is shown in Figure 13. At the lower and large part of the tube lead shot is placed and sealed in with wax. At the upper end of the glass tube the numbers 1.100, 1.150, 1.200, 1.250, 1.300 appear. This glass tube is placed in a larger glass container, the top of which is fitted with a rubber bulb for drawing the electrolyte into the container and in which the hydrometer floats. See Figure 14. When the hydrometer floats, the point on the scale at which it remains

stationary indicates the weight of the liquid. In a solution having a large proportion of acid the hydrometer will not sink as deeply as in the liquid devoid of acid, or mostly water.

Figure 15 shows a battery, the electrolyte of which is mostly water, giving a hydrometer reading of 1.100. Figure 16 shows a solution heavy with acid reading 1.300. In the first the hydrometer sinks deep into the solution while in the latter it does not sink to the same depth indicating in the first instance a discharged battery and, in the latter, a charged battery.

PREPARING THE ELECTROLYTE

The very first thing that you must know under this heading is the care to be exercised in preparing electrolyte for lead-acid cells. You understand that this electrolyte is a combination of distilled water and sulphuric acid. The water is harmless but this cannot be said about the acid. Sulphuric acid in itself is a very destructive agent both to your clothes and parts of your body with which it may come in contact. If you spill acid on your hands or clothes it can be neutralized by quickly applying a solution of baking soda and water, or household ammonia.

There is another danger in handling water and sulphuric acid, however, that is not so easily taken care of and is caused by improperly combining the two. Remember this, - NEVER ADD WATER TO STRONG SULPHURIC ACID - For the reason that water and sulphuric acid, when combined, produce terrific heat and when water is added to the acid in large quantities steam is immediately generated which will blow the solution into your face and over your body resulting in severe acid burns and perhaps blindness.

ALWAYS ADD ACID SLOWLY TO THE WATER. Follow these instructions when mixing the acid electrolyte and you may proceed with assured success. The water used should be distilled but if pure water is not easily obtained clean rain water which has not run through metal gutters and lead down pipes may be used. Clean snow melted in an earthen or glass receptacle will be satisfactory.

In mixing, add small quantities of acid to the water with the hydrometer, stirring carefully with a clean wooden stick until the proper specific gravity is obtained. The solution must be allowed to cool before it is placed in the battery.

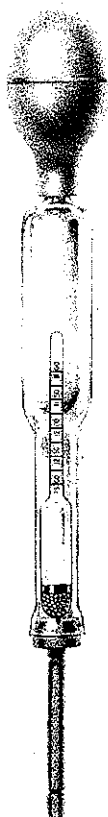


Figure 14

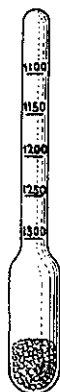


Figure 13

The manufacturers always specify in the instructions accompanying the battery the specific gravity of the electrolyte to be used with that particular battery, and their instructions should be carefully followed.

THE CHARGING OF BATTERIES

The charging of all storage batteries must be done with direct current. If direct current is not available alternating current must be changed to D.C. by the use of a rectifier. There are several good types of rectifiers on the market known chiefly as electrolytic and vacuum tube types.

Thus we find when alternating current is used for charging purposes it must first be rectified into a direct current by means of a rectifier. On the other hand when direct current is used it is a comparatively easy matter to charge storage batteries. The following explanations and diagrams may be used to accomplish the charging of batteries from a direct current source.

SHOWING CELL DISCHARGED
SPECIFIC GRAVITY 1100

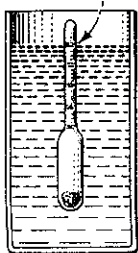


Figure 15

SHOWING CELL
FULLY CHARGED
SPECIFIC GRAVITY 1300

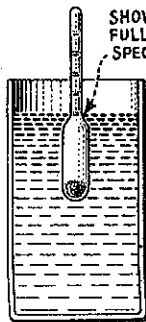


Figure 16

A bank of lamps or a resistance unit may be employed. First, however, we will find out how to determine the apparatus to be employed; this means that we must recall some of the formulae we learned in earlier lessons.

The direct current lighting mains in most homes have an E.M.F. of 110 volts and in our computations we will use that value. If, upon investigation, the line voltage is found to be higher, all that is necessary is to substitute the higher voltage in the formulae which will be given.

If we connect 110 volts directly across a storage battery a very high current would flow through the battery due to its low internal resistance. This is undesirable because a current too high in value will damage the plates by over-heating and buckling, therefore we must insert some sort of current limiting device in the circuit to prevent more than the required current to flow through the cells.

In our first problem we will study Figure 17 and use a resistance unit "R" which is placed in series with the line and storage battery, "B". Suppose we wish to charge the battery at the rate of 2 amperes; with the voltage of 110 volts known we can determine the watts dissipation necessary by the following formula:

$W = I \times E$, substituting the known values we have, $W = 2 \times 110$, where $I = 2$ and $E = 110$, therefore $W = 110 \times 2 = 220$ watts.

From this we find that with a resistance unit rated at 220 watts connected in series with one side of the D.C. line and the battery, the current entering the battery will be 2 amperes, the rate at which we wish to charge.

In most cases we like to know the value of the current limiting device in terms of resistance so, by employing Ohm's Law, we substitute our known values in the following formula, $R = E/I$, where $E = 110$ and $I = 2$ as before. Therefore $R = 110 \div 2$ or 55 ohms.

From this we find the required resistance to be 55 ohms and the ammeter, "A", when connected in the charging circuit as shown in Figure 17, will read 2 amperes.

Suppose we go a step further and check our computation to make sure that we are correct before actually connecting up the circuit. To do this we will use the formula, $W = I^2 \times R$. "I", we know, equals 2 amperes, and

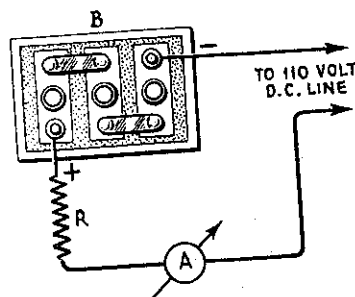


Figure 17

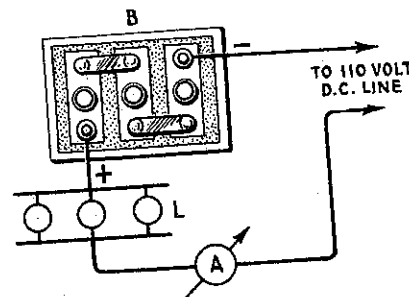


Figure 18

"R" we found to be 55 ohms. From our formula, however, "I" must be squared, that is, multiplied by itself, therefore by substituting we have:

$$\begin{aligned} W &= I^2 \times R \\ W &= 2^2 \times 55 \\ W &= 4 \times 55 = 220 \text{ watts.} \end{aligned}$$

Any rate of charge may be determined by changing the resistance value of "R" to meet the conditions required.

In Figure 18 is a circuit similar to that in Figure 17. Here we employ regular electric lamps, as found in any home, as current limiting or resistance devices. This is called the lamp bank method of charging any by using this method various charging rates may be obtained simply by changing lamps of either a higher or lower watt rating.

In Figure 18 place three lamps in the lamp receptacles at "L", each lamp rated at 25 watts. 3 lamps times 25 watts equals 75 watts. We know the voltage is 110 volts and having found the watts to be 75, the next step is to determine, with these values, the charging rate. To do this we must take our first formula which was written in terms of watts and from that derive a formula to meet this particular case.

If $W = I \times E$ then E is equal to W/I and I is equal to W/E . The formulae, therefore, derived from $W = I \times E$ is $E = W/I$ and $I = W/E$.

Referring to the first part of our problem we know that $E = 110$ and $W = 75$. By inspection, then, we find the formula $I = W/E$ will solve our problem in terms of amperes, and by substituting we have I equals $75/110$ or $0.68 +$ ampere.

$0.68 +$ ampere is a very slow rate of charge, so let us replace the three 25 watt lamps with three others; one having a rating of 400 watts, one of 25 watts, and the third 75 watts. 400 watts plus 25 watts plus 75 watts is a total of 500 watts. By formula $I = W/E$ and substituting our known values $I = 500/110$ or $I = 4.54$.

COMPUTING CHARGING RATES FROM FARM LIGHTING PLANTS

Farm lighting electric plants, in some instances, have a maximum voltage of 32 volts. The rules already given apply here as well as in circuits of 110 volts. Care must be taken, however, to substitute 32 for "E" instead of 110. For example, suppose you have a 6-volt storage battery and you wish to charge it at a rate of 4 amperes from a 32 volt farm lighting plant. $R = E/I$ and substituting $R = 32/4$ or 8 ohms. Eight ohms then is the required resistance.

PRECAUTIONS TO BE OBSERVED IN CHARGING FROM DIRECT CURRENT

Polarity must be correct. The positive of the charging source must be connected to the positive terminal of the battery. If no voltmeter is available to determine the polarity employ the water or potato test. Do not allow the leads to the battery to come in contact with grounded water or gas pipes or other metal objects which may be grounded. Do not charge at an excessive rate.

In the next lesson on storage batteries further application of this source of E.M.F. will be taken up together with the care and maintenance necessary to obtain highest efficiency and life from the storage battery.

EXAMINATION - LESSON 16

1. Name the active materials used in the storage battery plates.
2. What is the difference between a primary and secondary cell?
3. Of what is the electrolyte of the Exide cell composed?
4. What is meant by the ampere-hour capacity of a storage cell?
5. Draw a diagram of a simple charging circuit.
6. What is the specific gravity of the electrolyte of a fully charged Exide battery?
7. How would you mix acid with water when preparing the electrolyte?
Why?
8. (a) Explain the chemical action taking place in a cell on charge.
(b) On discharge.
9. What current would be obtained for charging a battery if a resistance of 55 ohms were used on a 110 volt charging line?
10. Of what use is a hydrometer?